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UNGUIDED ROCKET IMPACT DISPERSION AT WHITE SANDS MISSILE RANGE,--ETC(U)
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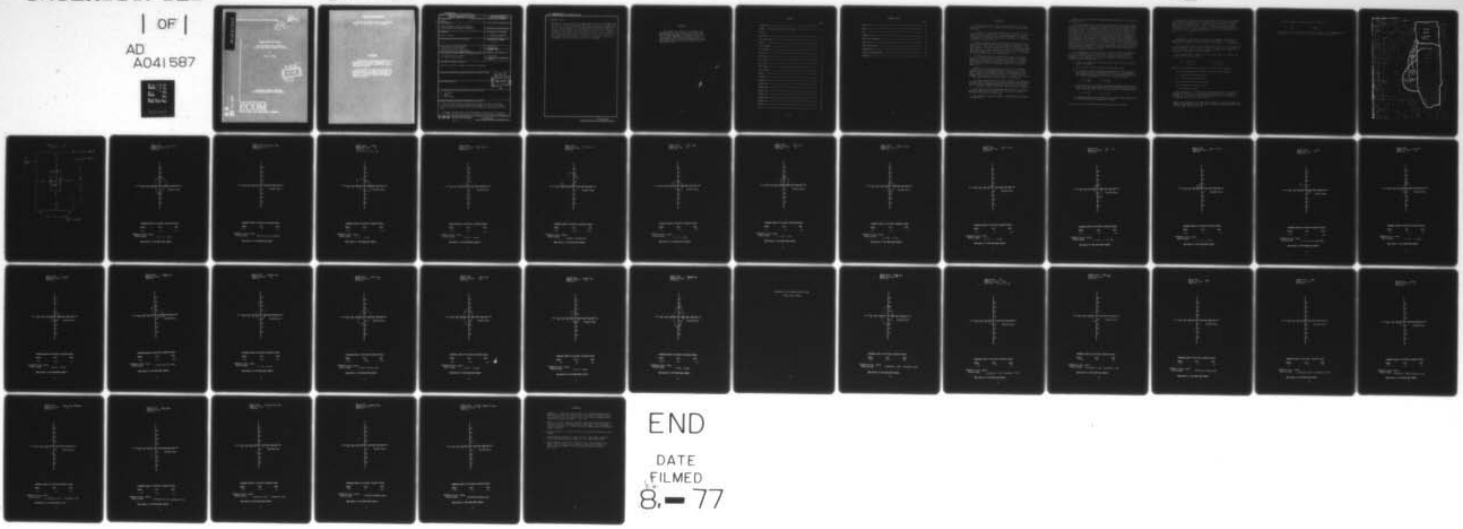

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March 1977

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METEOROLOGICAL DATA REPORT

UNGUIDED ROCKET IMPACT DISPERSION AT WHITE SANDS MISSILE RANGE, NEW MEXICO

BY

DAVID J. NOVLAN

ATMOSPHERIC SCIENCES LABORATORY
WHITE SANDS MISSILE RANGE, NEW MEXICO

ECOM
UNITED STATES ARMY ELECTRONICS COMMAND

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Impact dispersion data are presented for selected unguided sounding rockets launched from White Sands Missile Range, New Mexico, and from the Utah Launch Complex at Green River, Utah, during the six-year period 1970-1976.

Although dispersion data from 1965 forward could have been included in this report, the six-year period, 1970-1976 was chosen because of the more

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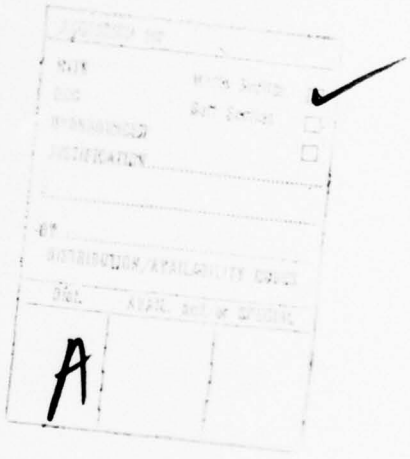
20. ABSTRACT (Cont)

sophisicated impact prediction and measurement techniques utilized during this period. A scatter diagram is presented for each rocket showing the area of primary dispersion of each shot around the predicted impact point. Included on each diagram is the standard error of estimate (total and component form) for each rocket type and the number of cases on which the calculations were based. All cases involving a known rocket malfunction were excluded from this study. In addition, theory on the deviations of "box limits" (T-90 second tower constraints) is presented, and actual recommended limits for each type of rocket are computed.

FOREWORD

This report is a revision of Data Report 821, "Unguided Rocket Impact Dispersion at White Sands Missile Range, New Mexico," published in March 1974. This revision summarizes the dispersion of many unguided missiles fired at White Sands Missile Range and the Utah Launch Complex at Green River, Utah, from 1970 to 1976.



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CONTENTS (CONT)

INTRODUCTION

The statistical scatter of the actual impact points about the predicted impact point of an unguided rocket is the rocket's impact dispersion.

The causes of rocket impact dispersion can be divided into five basic categories: 1) variations in atmospheric components, 2) variations in rocket components, 3) rocket misalignments, 4) launcher misalignments, and 5) factors which do not vary but are not precisely evaluated or are unaccounted for.

Before an unguided rocket is flight-tested, a theoretical dispersion study is usually performed to estimate its dispersion. This analysis can be made using a trajectory simulation program in a high-speed computer. The best estimates available of the perturbing factors can be put in the program, and the impact points can be compared with the nominal impact point. When this procedure is used, it is assumed that the perturbing factors act independently.

The six-year period from 1970-1976 was chosen for this study because of the more advanced and sophisicated impact prediction and measurement techniques used during this period; namely, T-9 radar pibal tracking, advanced Wang calculators utilized on hot firings, impact predictions using 5-D real-time systems (2), HP-97 field backups, etc.

Dispersion for each rocket firing is plotted on a Cartesian coordinate scatter diagram showing the misses around the predicted impact (origin of the coordinate system). The dispersion for each type of rocket is then analyzed in terms of the standard error of estimate (both total and in component form). All cases that involved a known rocket malfunction were not included in this study.

This report presents the actual impact dispersion of twenty-four unguided rockets fired at White Sands Missile Range (WSMR), New Mexico, or the Utah Launch Complex, Green River, Utah, for the period 1970-1976. No attempt is made to isolate the various causes of dispersion.

The actual impact points were taken from surveys when available. Elsewhere, radar or Sonic Observation of Trajectory and Impact of Missiles (SOTIM) impact data were used.

This information should be helpful for range planning and safety considerations.

Figure 1 shows the White Sands Missile Range (regular Range) along with its extended borders.

For major unguided rocket launches (excluding small meteorological rockets fired from Small Missile Range), one of the major factors influencing the impact predictor's decision to recommend fire, delay or hold is the constraint put on the 500 foot winds. This constraint is referred to as the "box limits." For most unguided rocket firings, nearly 50% of the wind weighting has occurred in the lowest 500 feet of its trajectory after lift-off with nearly 75-85% of the total correction experienced by the time the rocket has flown some 4000 feet after lift-off. These box limits are computed around T-90 to T-60 seconds, and the weighted 500 foot average wind is allowed to wander inside these limits up to T-0 to assure a safe firing. If the variability of the wind is such that the weighted 500 foot wind during this crucial part of the count-down wanders outside these limits, then a delay count or a hold is initiated. The actual positioning of these limits is determined by the total displacement in the 500 foot wind at finals time* and the change in the weighted winds from 4500-8000 feet mean sea level from the latest two balloon runs.

It is recommended that the actual size of these box limits be determined by the following method or at least have this procedure serve as guidance. Using the statistics compiled in this report (namely the components of the standard error of estimate), the missile range (regular boundaries) will be reduced as follows (see Figure 2):

1. Utilize a 40 mile wide, 65 mile long missile range (that is the range north of the WSNM).

2. Use the center of this rectangular range as impact point.

3. As in Figure 2 reduce the east-west boundaries by coming in $2S_x$ from each boundary (where S_x has been defined previously) and analogously for reducing the north-south boundaries. This will produce box limits of +/- X for the east-west and +/- Y for the north-south where:

$$X = \frac{40 - 2S_x}{2} \qquad Y = \frac{65 - 2S_y}{2}$$

4. In the event it is not possible to centralize the impact point and the impact point is located A miles east of the western boundary and B miles north of the WSNM, then use the following formula to obtain box limits.

$$X = A - 2S_x \qquad Y = B - 2S_x$$

5. If extended range land is utilized for the rocket firing, then the east-west box limits may be extended some 2-4 miles.

* That is the time the final launcher setting angles were determined.

Theoretically this should insure a 95% probability of impact on the missile range (recall the properties of the standard error of estimate are similar to those of the standard deviation). An Aerojet Corporation report would give a lower probability (86-87%) (see Reference 4) where if the inrange standard deviation of the impact point is 6_y and the crossrange standard deviation is 6_y, the probability (p) of impacting within an ellipse with an inrange semi-axis of $K6_y$ and a crossrange semi-axis of $K6_y$ is:

$$p = 1 - e^{-K^2/2}$$

Although some of the dispersion statistics may suggest rather large box limits, practical experience has shown that it is probably not a good policy to let box limits exceed +/- 15 on the north-south and +/- 10 on the east-west.*

It can be readily seen from the formulae that calculate the box limits, that since A <40 and B <65 that to utilize maximum box limits (that is take advantage of the two standard error or estimate lengths), the impact point should be centralized in the range as much as possible.

The standard error of estimate for rocket impact points in component form is given by the following formula:

$$S_y = \frac{\sum_i^m (y_i - y_n)^2}{m} \qquad S_x = \frac{\sum_i^m (X_i - X_n)^2}{m}$$

where S_y is the standard error estimate for the y(N/s) miss component.

S_x is the standard error estimate for the x(e/w) miss component.

Y is the actual north-south impact.

X is the actual east-west impact.

Y_n is the predicted north-south impact.

X_n is the predicted east-west impact.

n is the number of cases.

The standard error of estimate has properties analogous to the standard deviation (3); namely, for a large sample, one standard error of estimate comprises 68% of the sample; two standard deviations, like two standard error of estimates, have 95% of the sample and so on.

* Based on the premise that the larger the allowable box limits, the larger the permitted wind variability will be; thus, the larger the uncertainty introduced into the impact prediction will be.

For small samples, S_y and S_x should be replaced by

$$S_y \quad \frac{m}{m-2} \qquad\qquad S_x \quad \frac{m}{m-2}$$

respectively. This modification is likewise analogous to the standard deviation. The standard error of estimate of the total rocket miss is $(S_x^2+S_y^2)^{1/2}$.

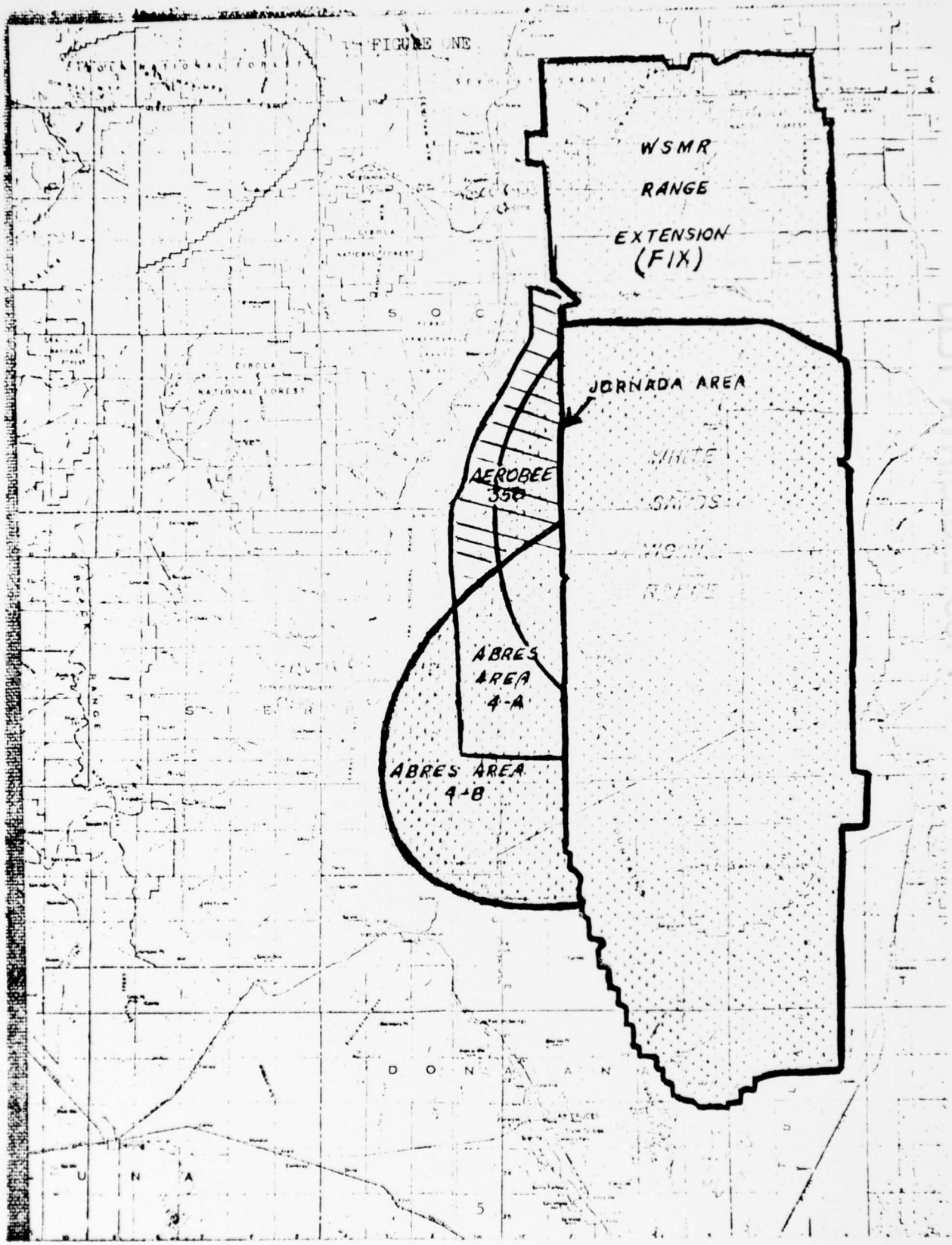
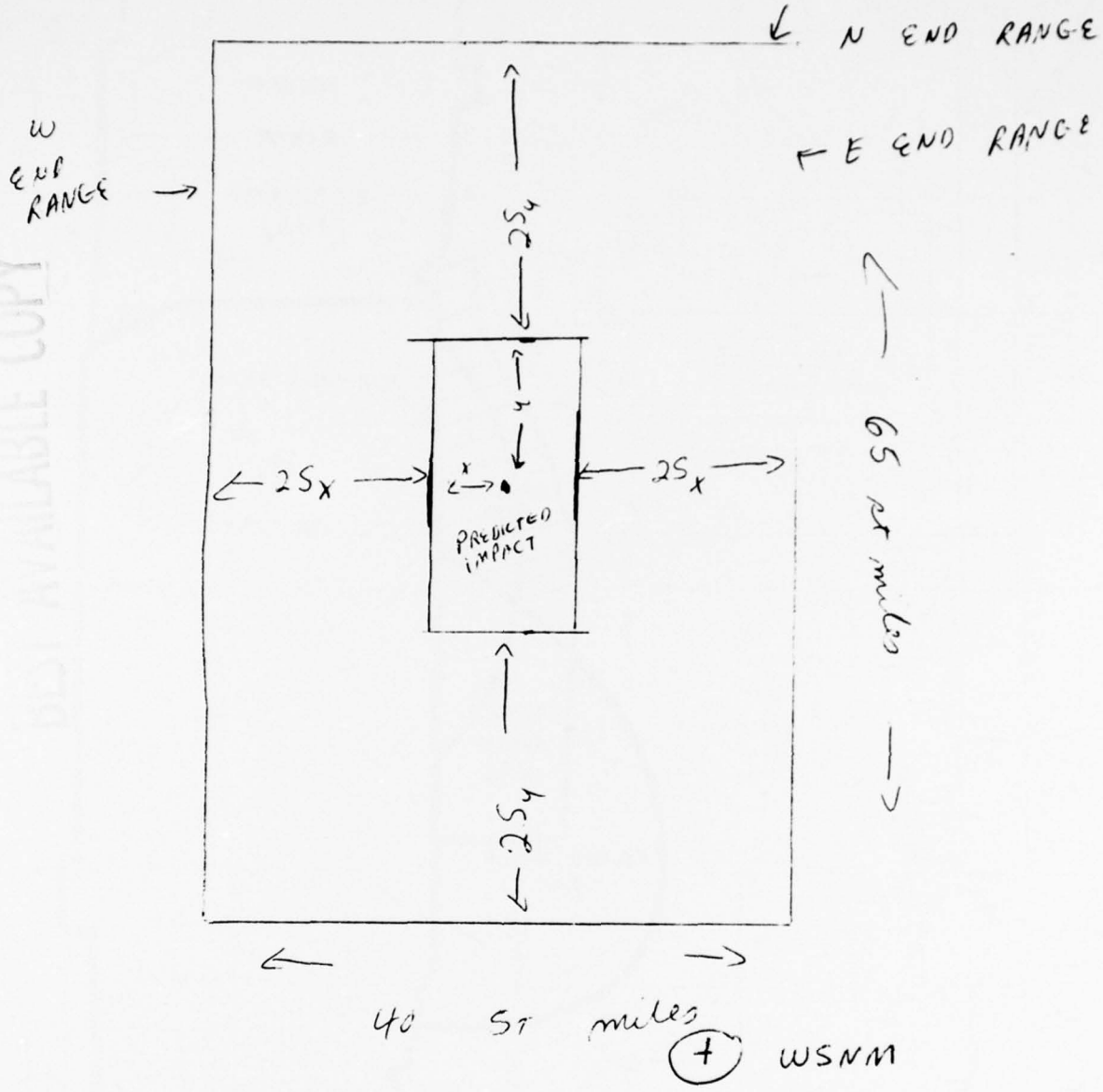
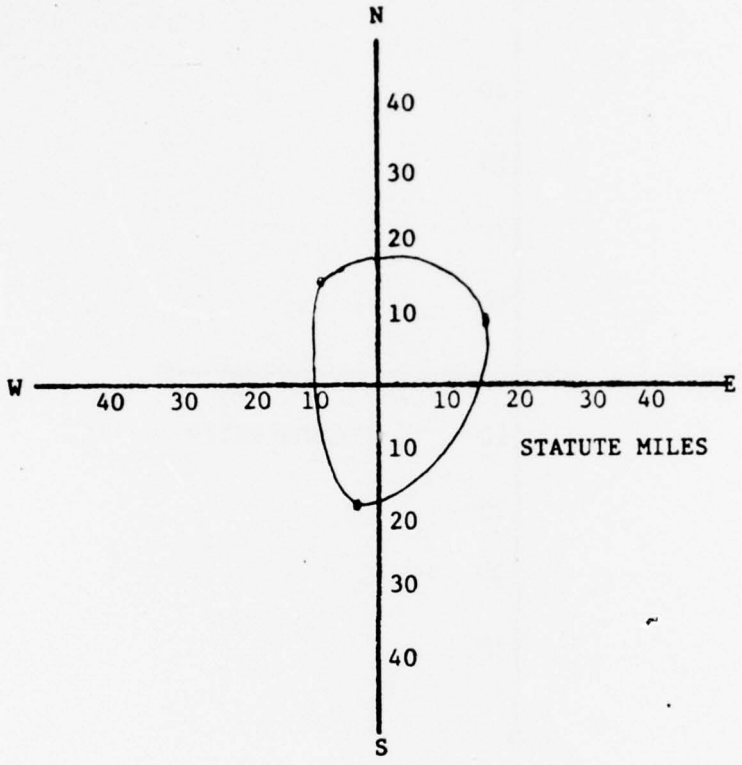


FIGURE 2



ROCKET TYPE: BLACK BRANT
NUMBER OF CASES: 27
1970-1976



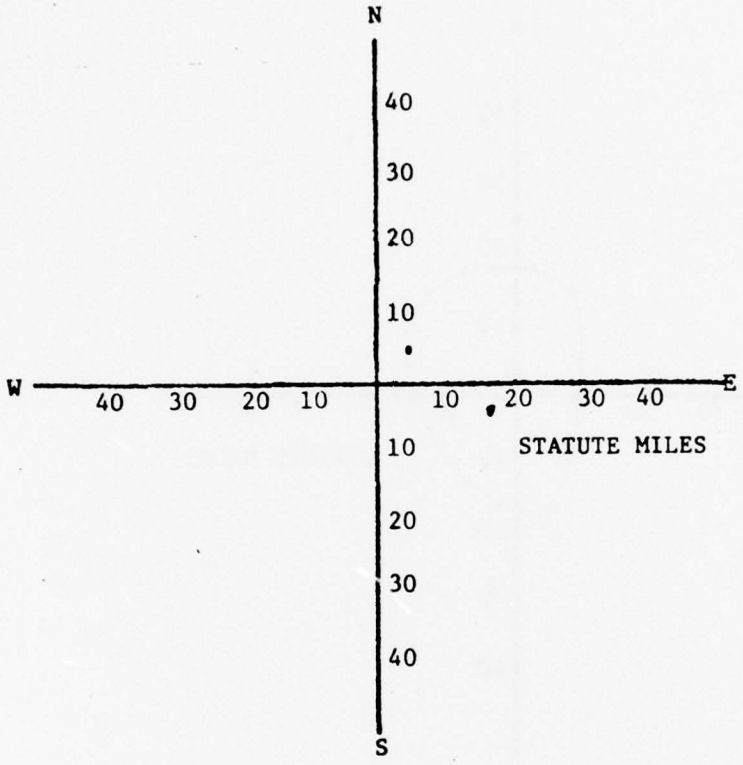
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
10.7	8.0	7.0

RECOMMENDED BOX LIMITS
REGULAR RANGE +-15 NS +- 6 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: NIKE BLACK BRANT
NUMBER OF CASES: 2
1970-1976



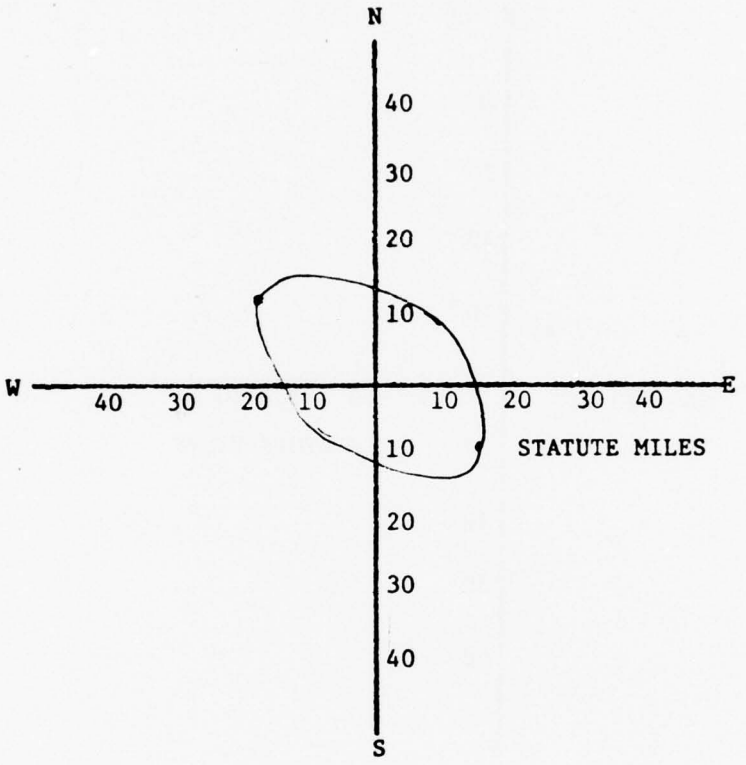
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
9.5	.4	9.5

RECOMMENDED BOX LIMITS
REGULAR RANGE EXTENDED RANGE RECOMMENDED

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: ATHENA
NUMBER OF CASES: 21
1970-1976
GREEN RIVER UTAH TO WSMR



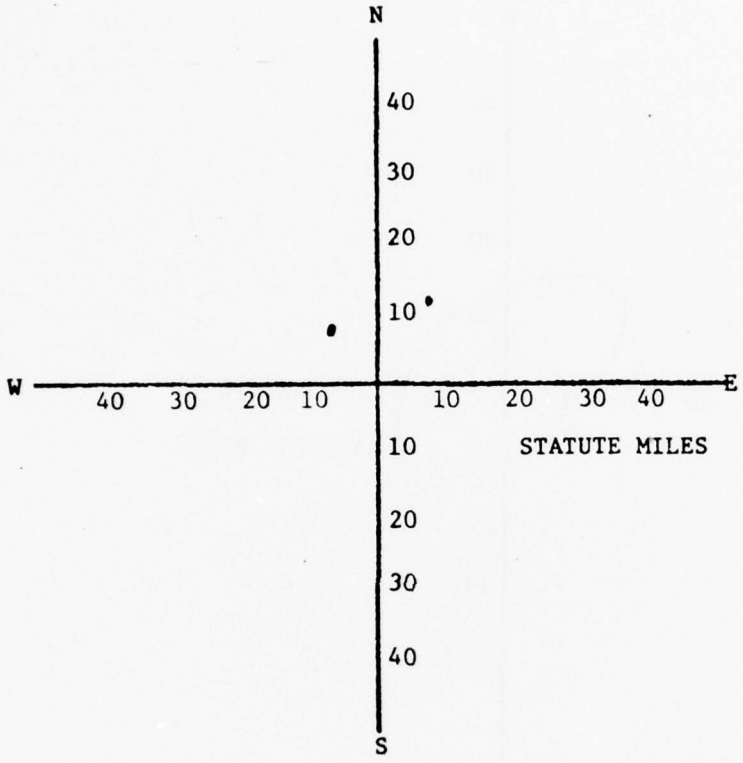
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
13.8	7.1	11.8

RECOMMENDED BOX LIMITS
REGULAR RANGE +-9 NS +-6 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: PIUTE TOMAHAWK
NUMBER OF CASES: 2
1970-1976



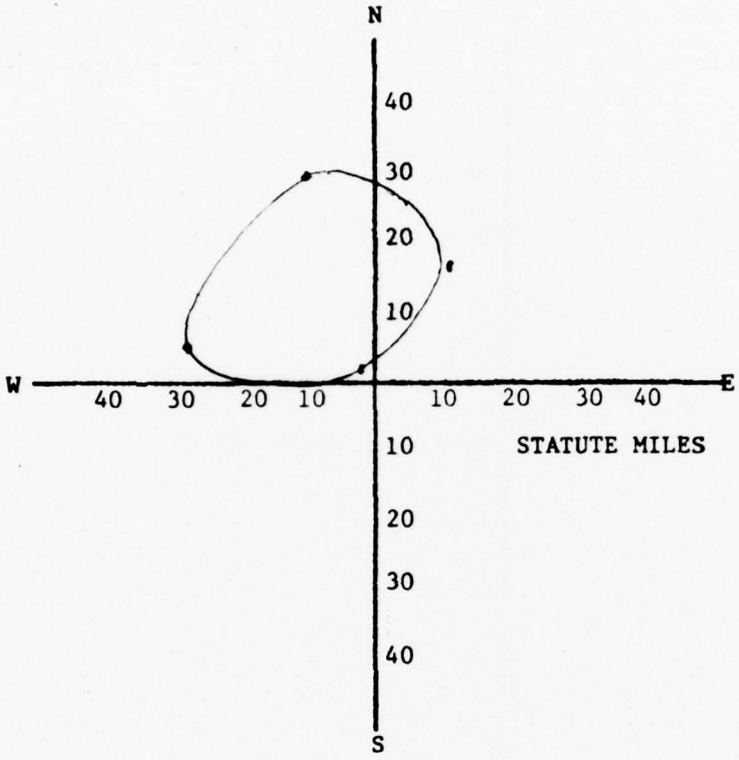
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
12.7	9.6	8.3

RECOMMENDED BOX LIMITS
REGULAR RANGE +-13 NS +-3 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: UTE TOMAHAWK
NUMBER OF CASES: 4
1970-1976



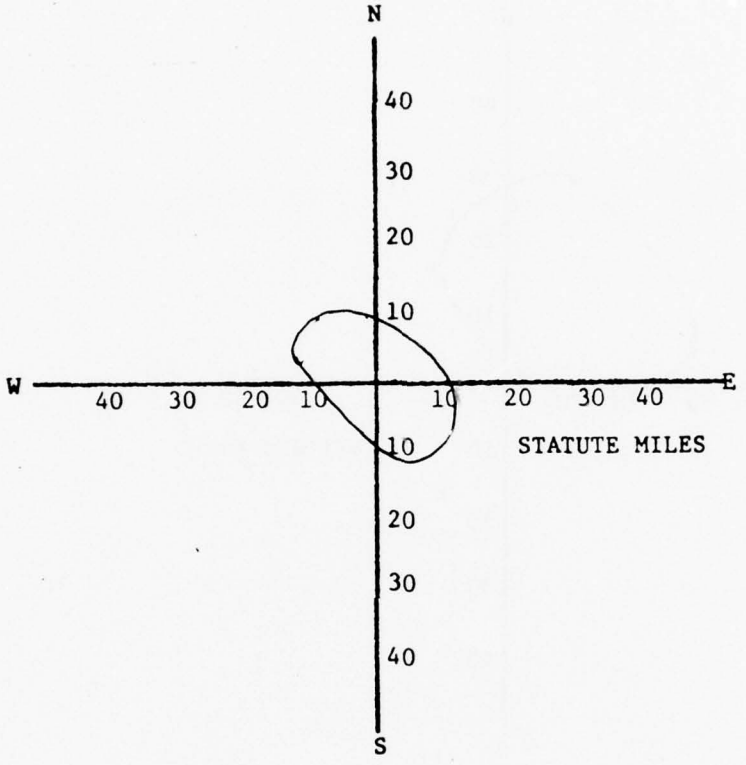
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
24.2	17.6	16.6

RECOMMENDED BOX LIMITS
REGULAR RANGE
RECOMMEND EXTENDED LAND

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: NIKE CAJUN
NUMBER OF CASES: 15
1970-1976



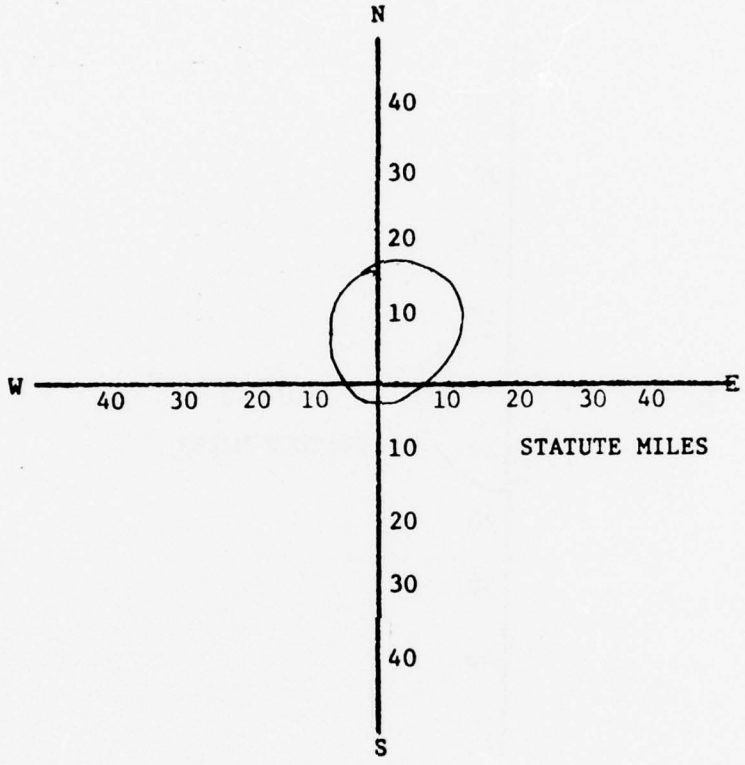
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
7.7	5.1	5.8

RECOMMENDED BOX LIMITS
REGULAR RANGE +- 15 NS +-8 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: NIKE HYDAC
NUMBER OF CASES: 13
1970-1976



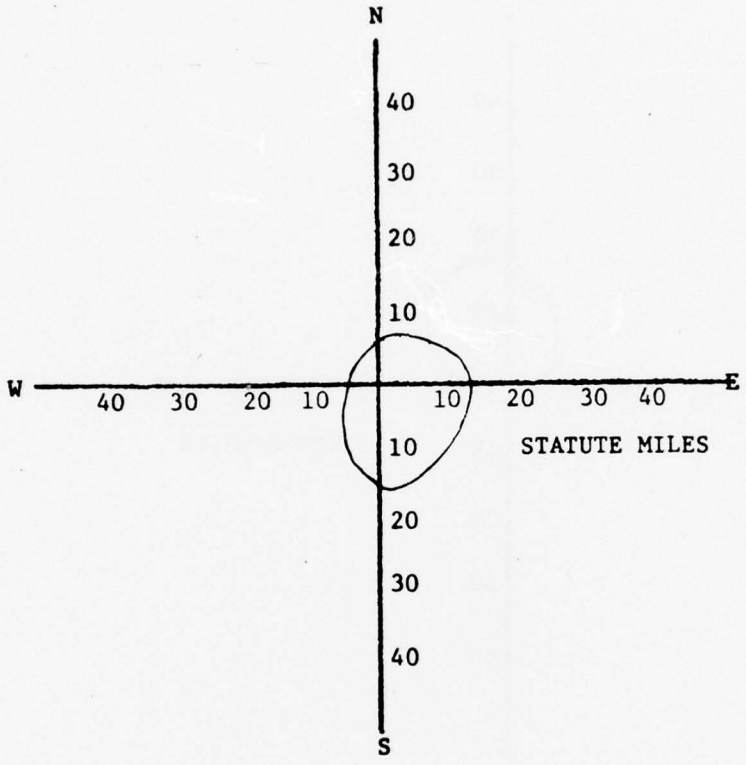
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
8.4	5.4	6.4

RECOMMENDED BOX LIMITS
REGULAR RANGE +- 15 NS +-7 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: NIKE IROQUOIS
NUMBER OF CASES: 6
1970-1976



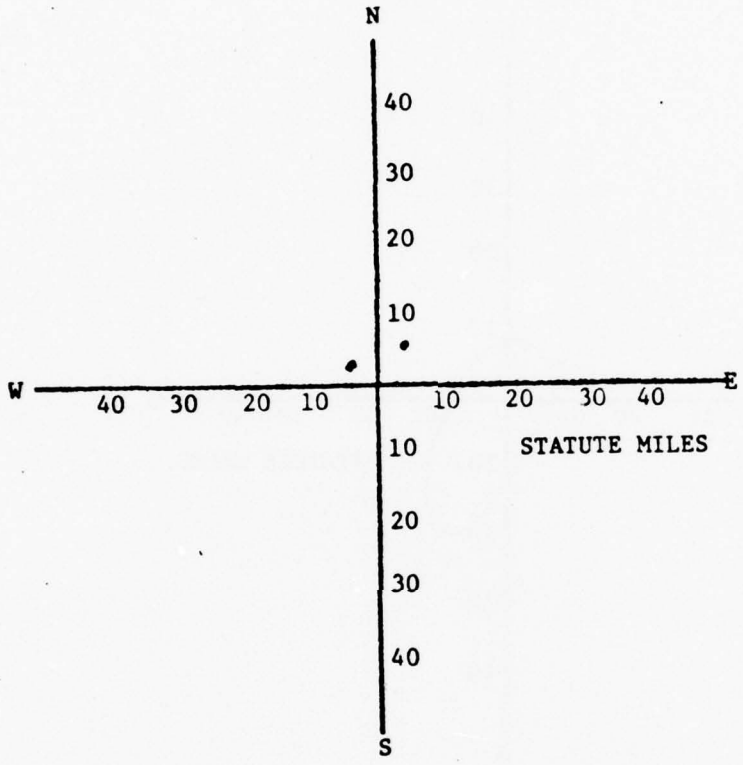
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
8.7	6.7	5.5

RECOMMENDED BOX LIMITS
REGULAR RANGE
+-15 NS +- 9 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: NIKE JAVELIN
NUMBER OF CASES: 2
1970-1976



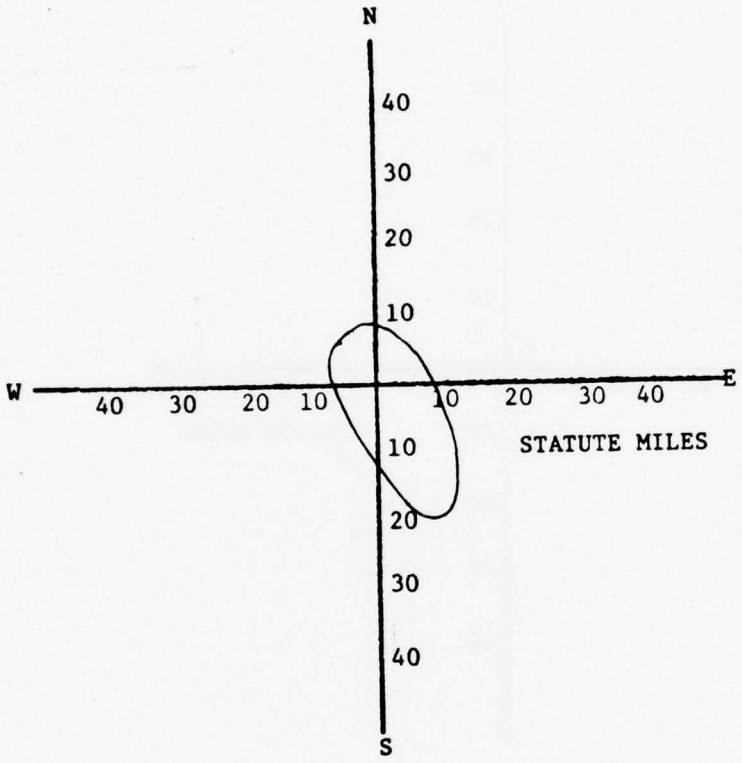
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
6.7	5.5	3.9

RECOMMENDED BOX LIMITS
REGULAR RANGE +-15 NS +- 10 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: NIKE APACHE
NUMBER OF CASES: 11
1970-1976



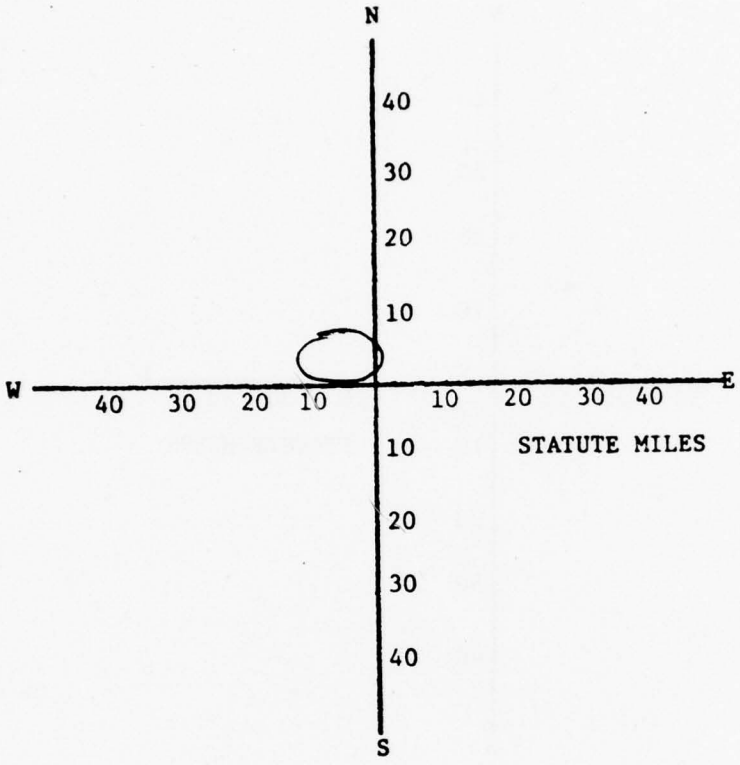
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
8.9	7.8	4.3

RECOMMENDED BOX LIMITS
REGULAR RANGE +- 15 NS +- 10 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: NIKE POMAHAWK
NUMBER OF CASES: 4
1970-1976



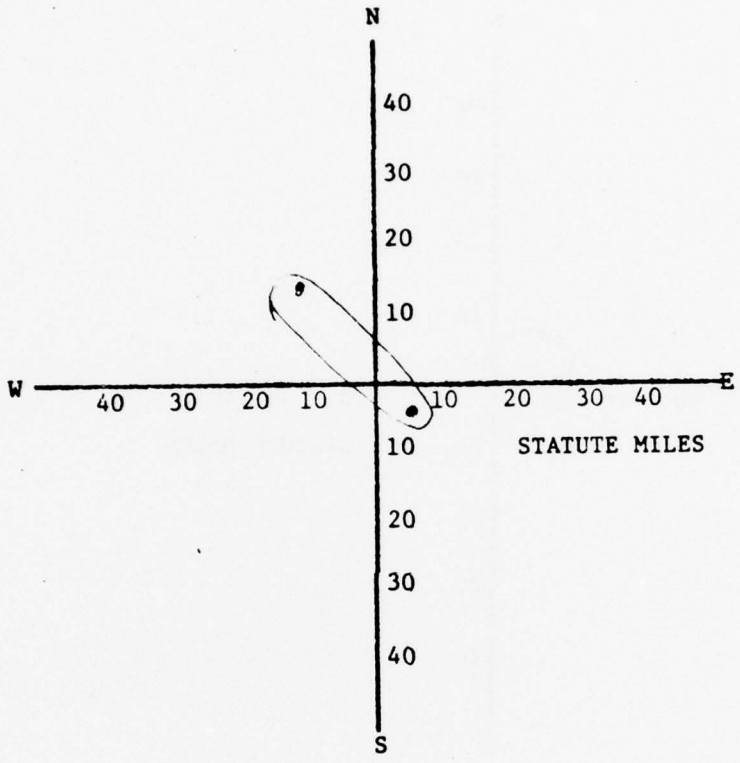
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
10.6	6.2	8.6

RECOMMENDED BOX LIMITS
REGULAR RANGE
+- 15 NS +-3 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: H..RSES
NUMBER OF CASES: 5
1970-1976



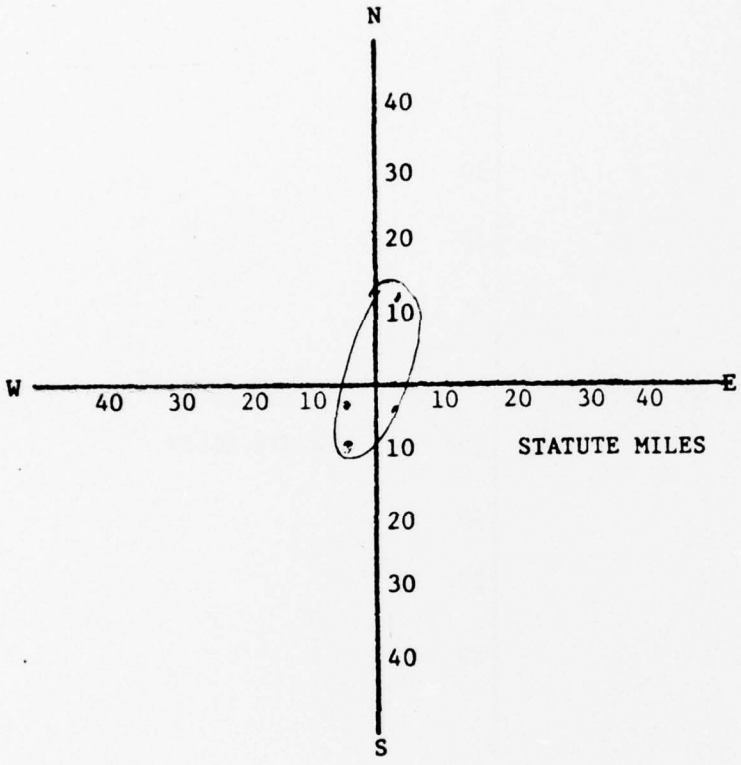
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
12.5	7.6	9.9

RECOMMENDED BOX LIMITS
REGULAR RANGE EXTENDED LAND RECOMMENDED

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: ASTROBEE D
NUMBER OF CASES: 14
1970-1976



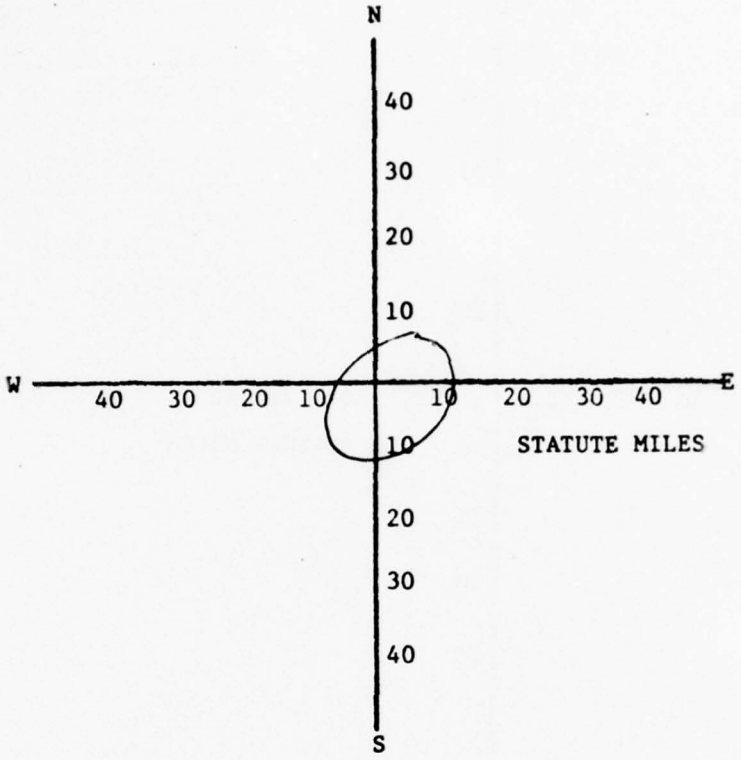
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
8.3	6.9	4.6

RECOMMENDED BOX LIMITS
REGULAR RANGE +- 15 NS +- 10 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: ASTROBEE F
NUMBER OF CASES: 5
1970-1976



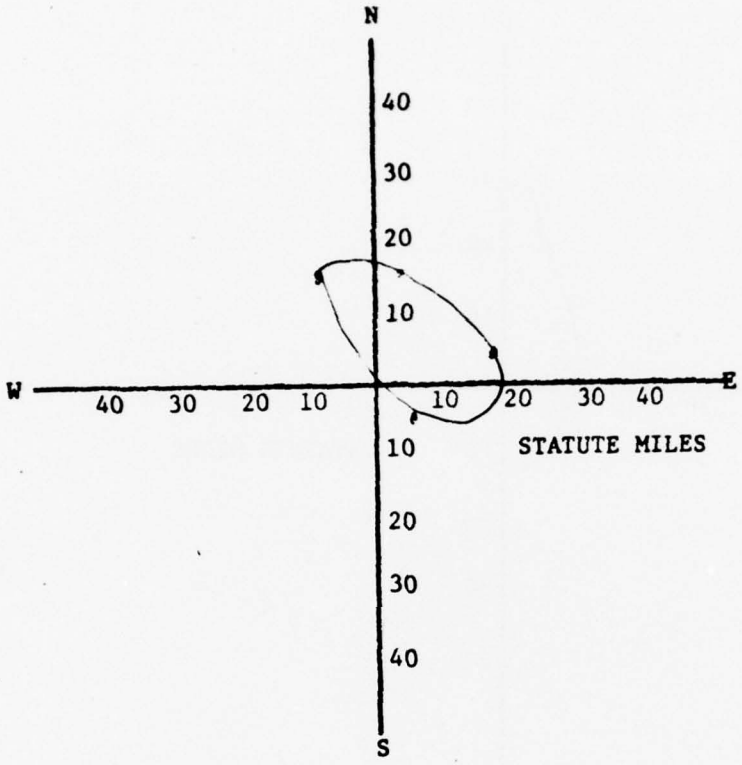
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
12.6	11.2	6.2

RECOMMENDED BOX LIMITS
REGULAR RANGE +-10 NS +-7 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: AEROBEE 350
NUMBER OF CASES: 9
1970-1976



STANDARD ERROR OF ESTIMATE (STATUTE MILES)

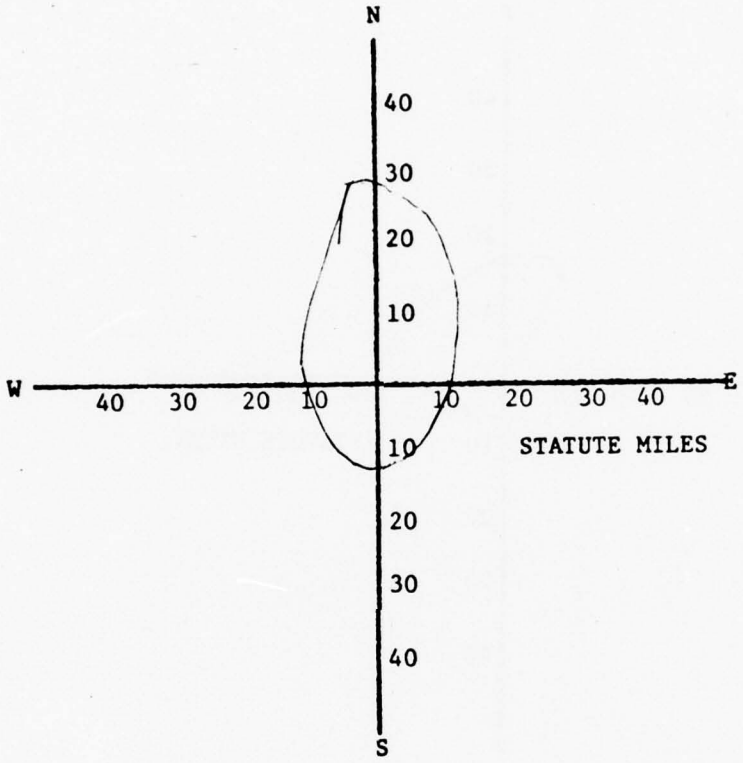
TOTAL	N/S	E/W
19.0	15.4	11.2

RECOMMENDED BOX LIMITS
REGULAR RANGE

RECOMMENDED EXTENDED LAND

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: AEROBEE 200A
NUMBER OF CASES: 34
1970-1976



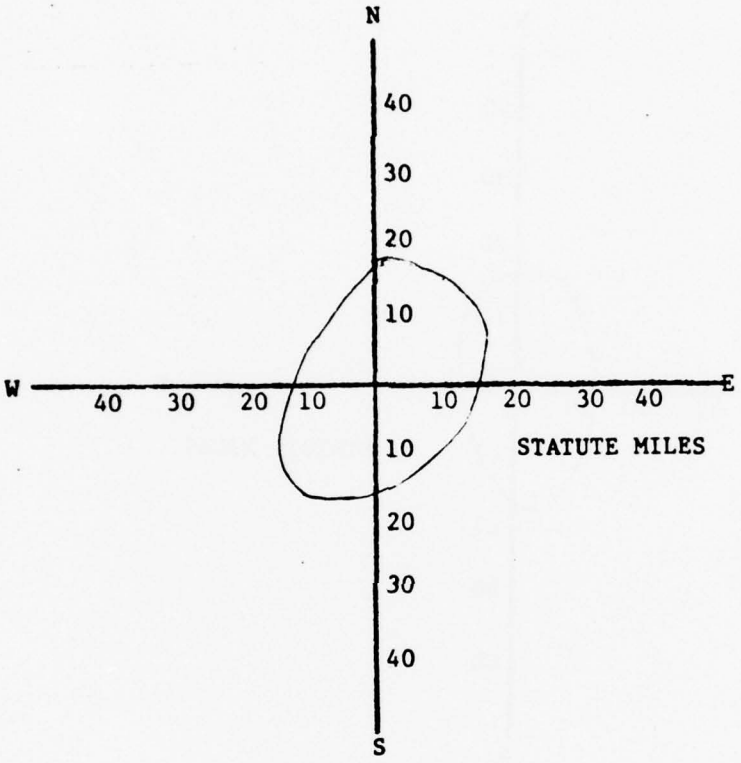
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
8.6	11.9	6.9

RECOMMENDED BOX LIMITS
REGULAR RANGE +- 15 NS +-6 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: AEROBEE 200
NUMBER OF CASES: 8
1970-1976



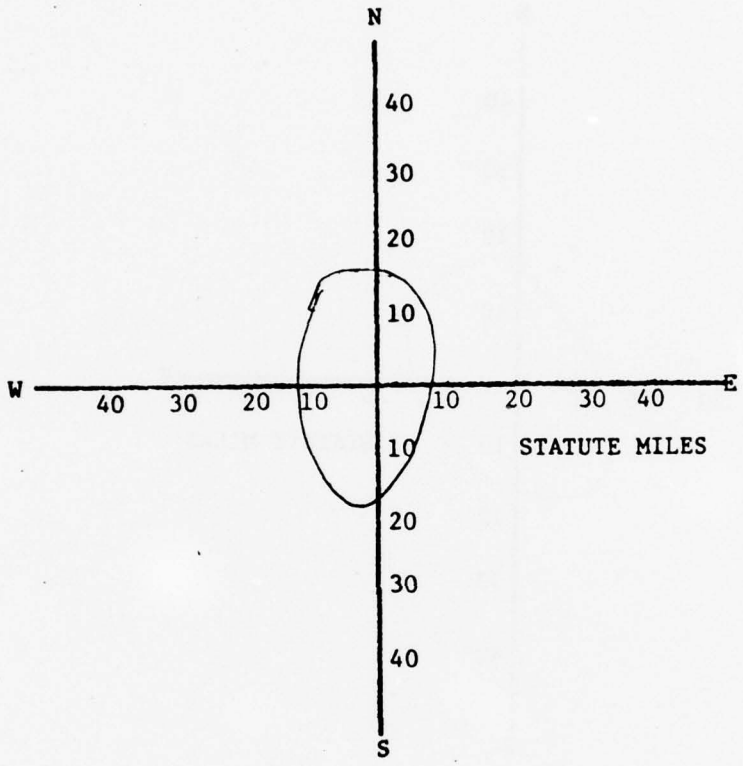
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
18.5	13.6	12.5

RECOMMENDED BOX LIMITS
REGULAR RANGE RECOMMED EXTENDED LAND

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: AEROBEE 150
NUMBER OF CASES: 44
1970-1976



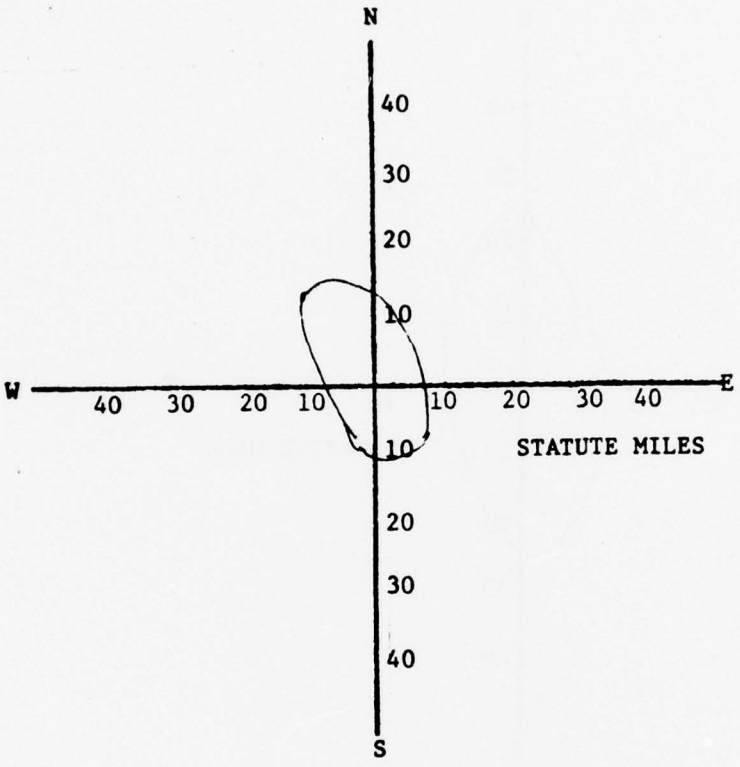
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
9.9	8.3	5.3

RECOMMENDED BOX LIMITS
REGULAR RANGE +-15 NS +- 9 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: AEROBEE 170A
NUMBER OF CASES: 22
1970-1976



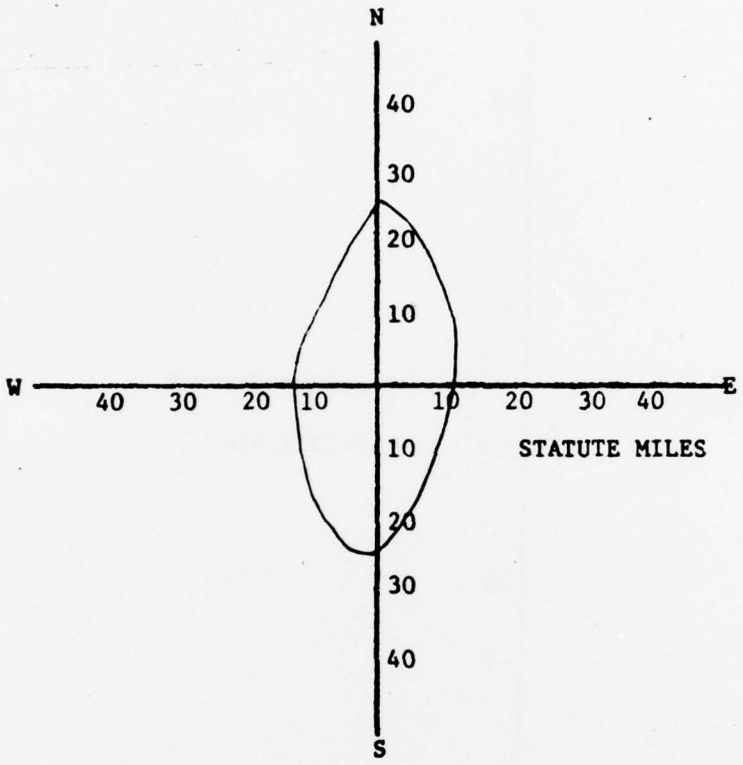
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
7.8	5.9	5.1

RECOMMENDED BOX LIMITS
REGULAR RANGE +-15 NS +-9 EW

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: AEROBEE 170
NUMBER OF CASES: 67
1970-1976



STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
13.9	11.8	7.4

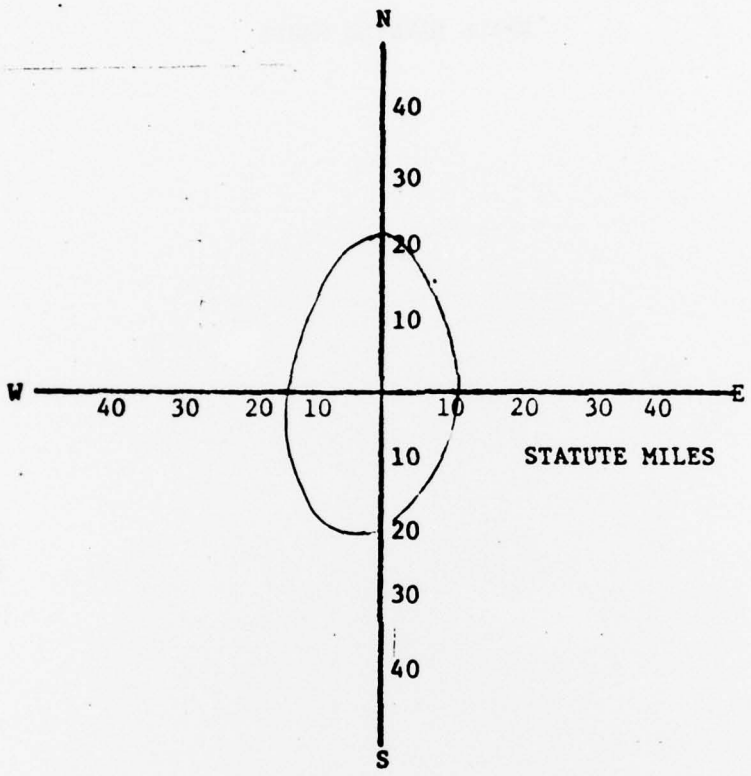
RECOMMENDED BOX LIMITS
REGULAR RANGE +- 9NS +-5 EW

THE ORIGIN IS THE PREDICTED IMPACT.

UNGUIDED MISSILE FIRINGS FROM THE WSMR

SMALL MISSILE RANGE

ROCKET TYPE: VIPER LOKI
NUMBER OF CASES: 31
1970-1976



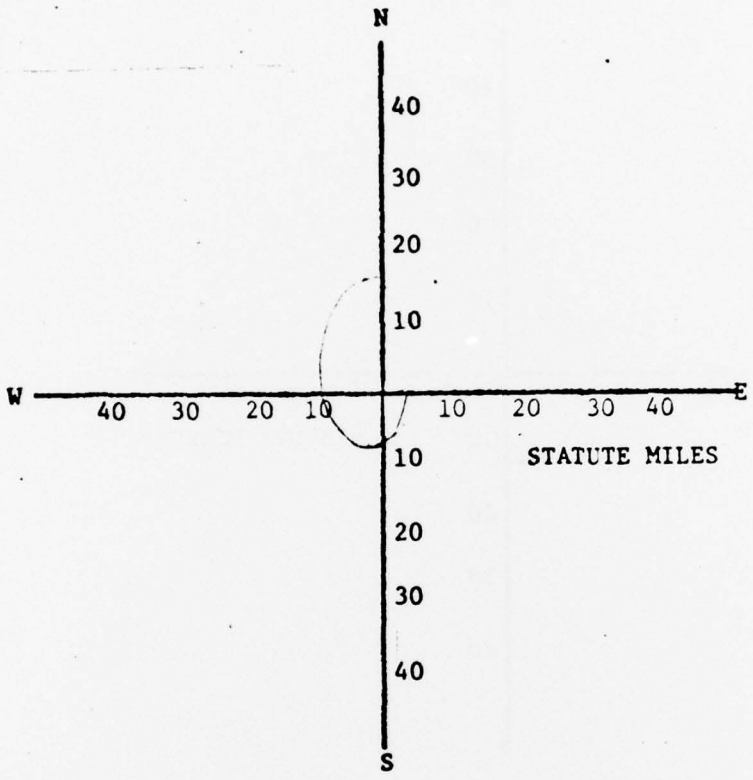
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
10.4	8.9	5.3

RECOMMENDED BOX LIMITS
REGULAR RANGE plus/minus 5 N/S plus/minus 5 E/W

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: LOKI
NUMBER OF CASES: 144
1970-1976 (1975-1976 sample)



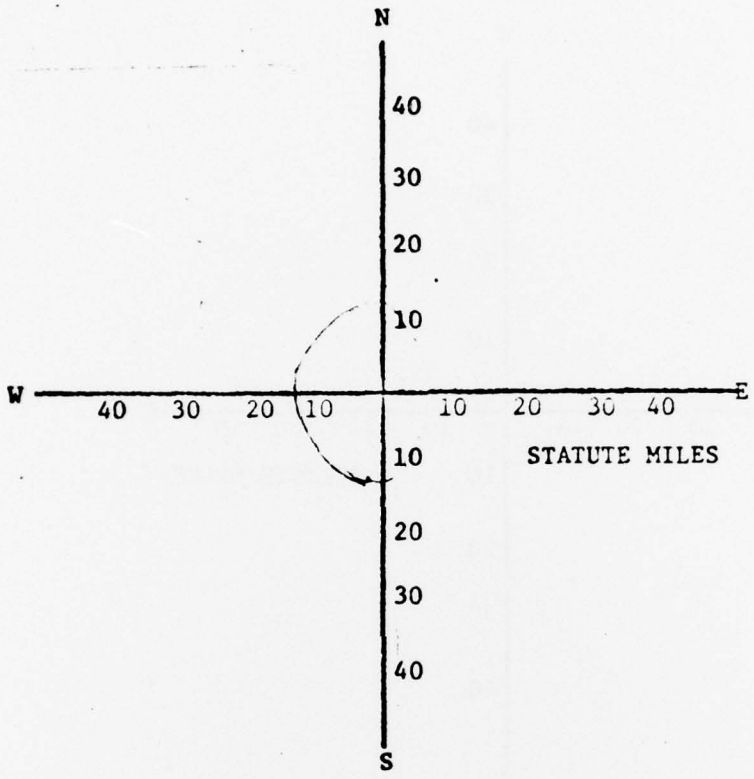
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
5.73	4.1	4.0

RECOMMENDED BOX LIMITS
REGULAR RANGE plus/minus 7 N/S plus/minus 7 E/W

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: SUPER LOKI
NUMBER OF CASES: 149
1970-1976



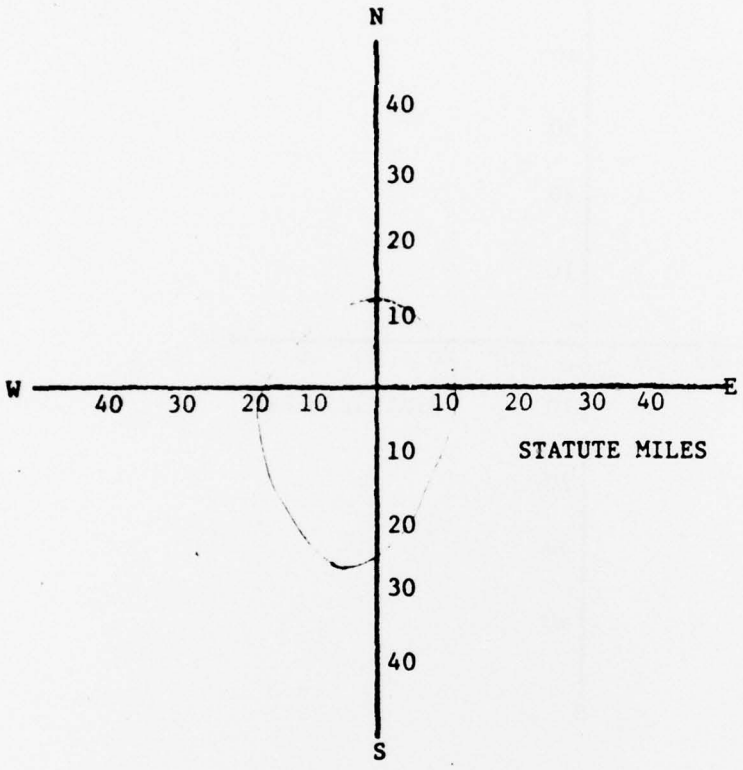
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
6.74	5.7	3.6

RECOMMENDED BOX LIMITS
REGULAR RANGE plus/minus 4 N/S plus/Minus 7 E/W

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: RDTE
NUMBER OF CASES: 89
1970-1976



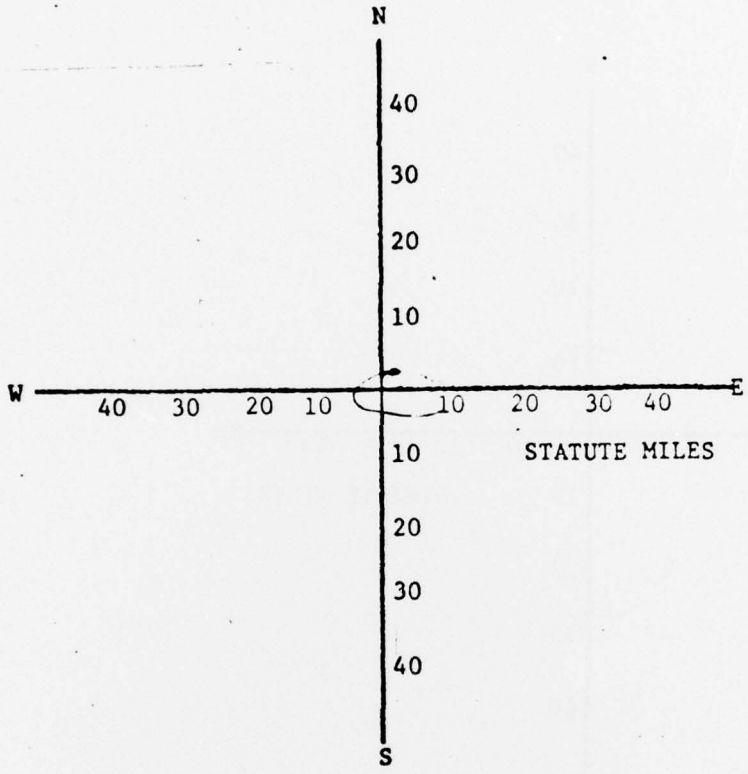
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
11.2	8.5	7.3

RECOMMENDED BOX LIMITS
REGULAR RANGE plus/minus 3 N/S and E/W

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: MDSS
NUMBER OF CASES: 5
1970-1976



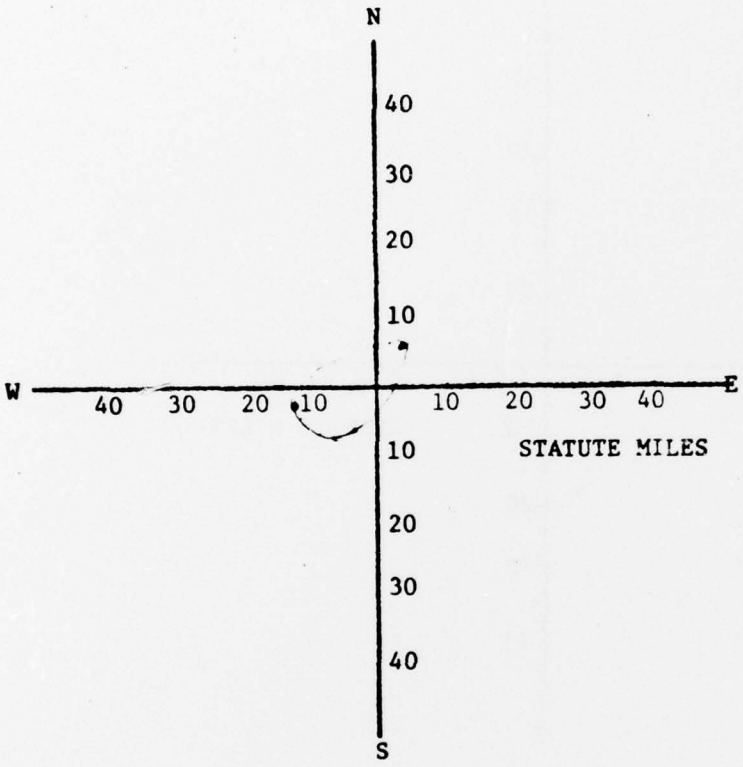
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
5.2	1.4	5.0

RECOMMENDED BOX LIMITS
REGULAR RANGE plus/minus 13 N/S plus/minus 5, E/W

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: QUANNAH
NUMBER OF CASES: 12
1970-1976



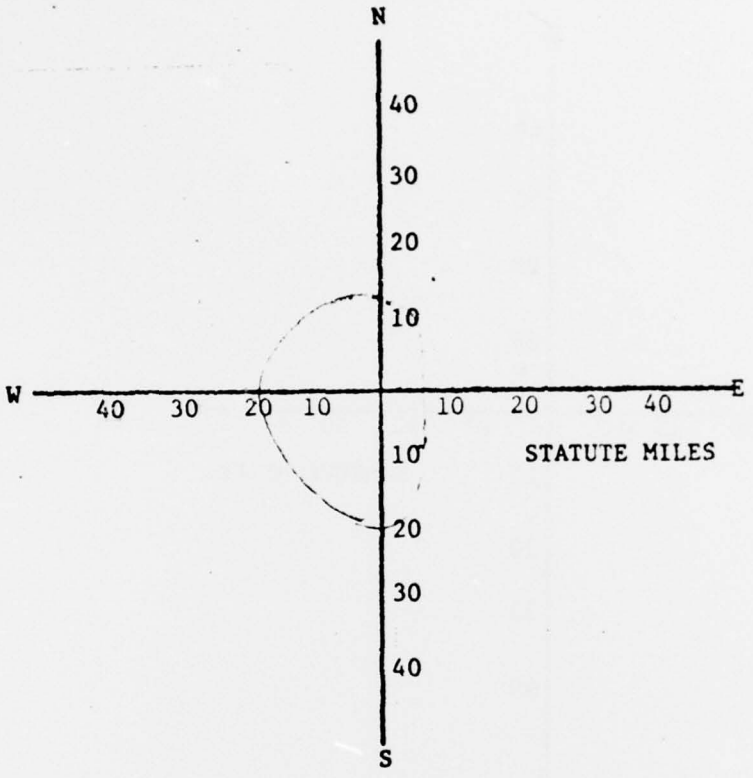
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
8.2	4.5	6.8

RECOMMENDED BOX LIMITS
REGULAR RANGE plus/minus 5 N/S plus/minus 4 E/W

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: ARCAS (GAS GENERATED)
NUMBER OF CASES: 183
1970-1976



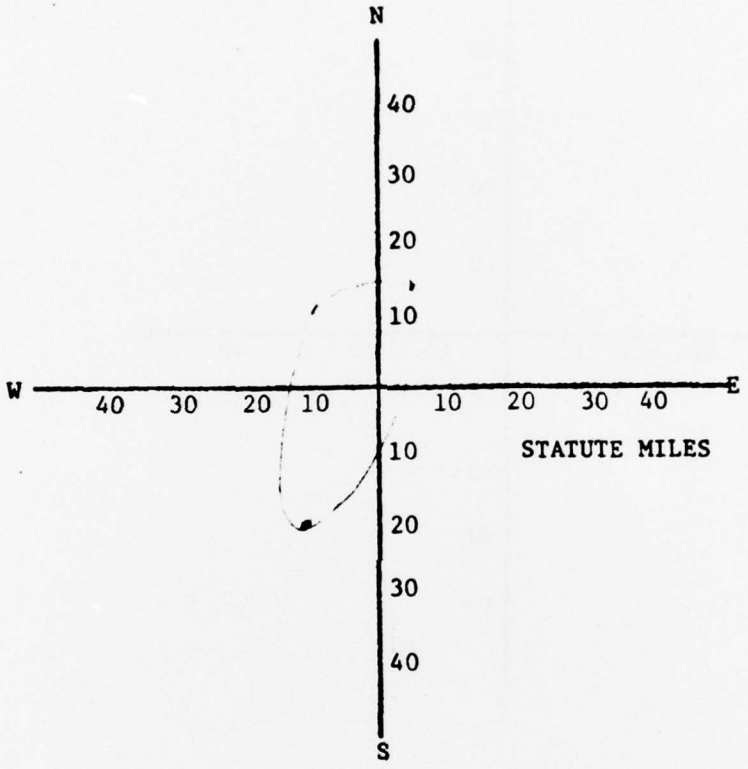
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
9.0	6.9	5.8

RECOMMENDED BOX LIMITS
REGULAR RANGE plus/minus 3 N/S plus/minus 5 E/W

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: SUPER ARCAS
NUMBER OF CASES: 6
1970-1976



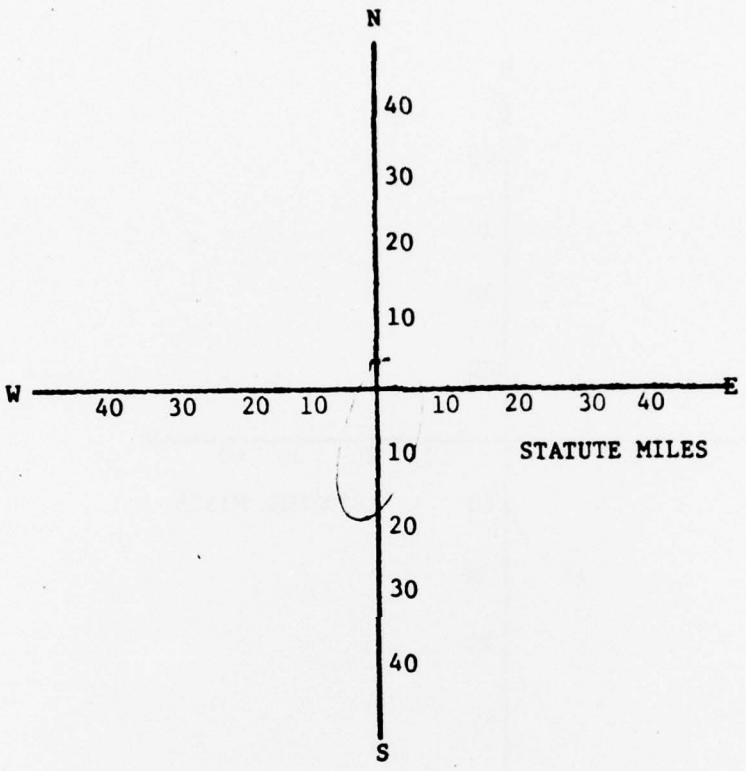
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
15.6	13.6	7.7

RECOMMENDED BOX LIMITS
REGULAR RANGE plus/minus 10 N/S plus/minus 3 E/W

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: HVAR BOOSTED ARCAS
NUMBER OF CASES: 4
1970-1976



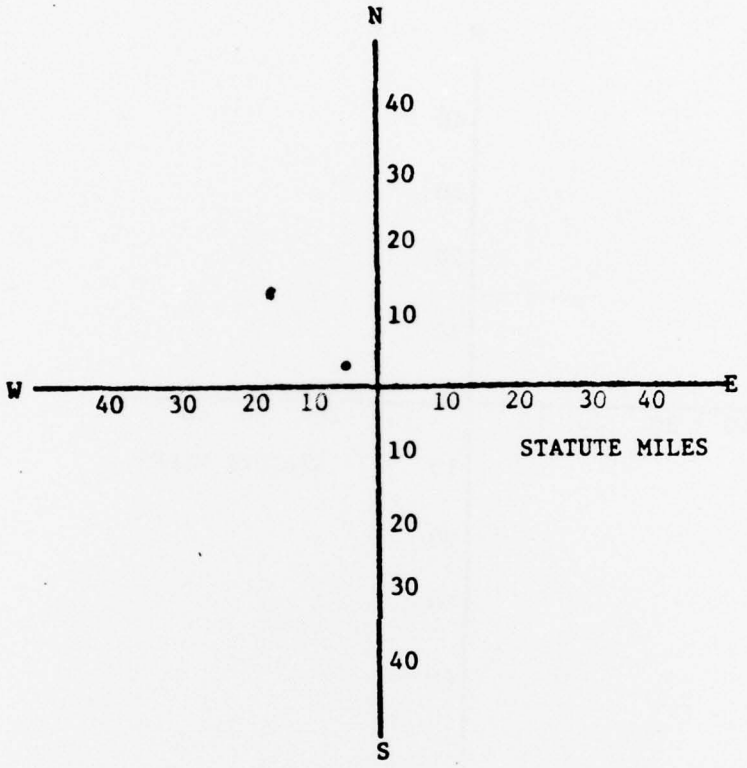
STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
11.0	10.4	3.7

RECOMMENDED BOX LIMITS
REGULAR RANGE plus/minus 5 N/S plus/minus 8 E/W

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: SPARROW ARCAS
NUMBER OF CASES: 2
1970-1976



STANDARD ERROR OF ESTIMATE (STATUTE MILES)

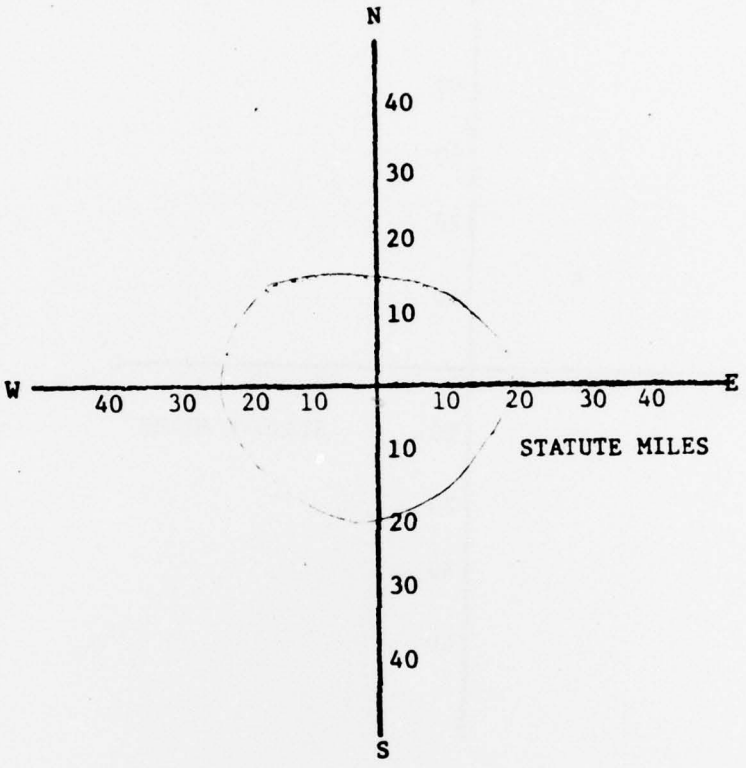
TOTAL	N/S	E/W
15.6	8.9	12.7

RECOMMENDED BOX LIMITS
REGULAR RANGE

RECOMMEND EXTENDED RANGE

THE ORIGIN IS THE PREDICTED IMPACT.

ROCKET TYPE: BOOSTED SIDEWINDER ARCAS
NUMBER OF CASES: 24
1970-1976



STANDARD ERROR OF ESTIMATE (STATUTE MILES)

TOTAL	N/S	E/W
12.5	8.0	9.6

RECOMMENDED BOX LIMITS
REGULAR RANGE RECOMMEND EXTENDED RANGE

THE ORIGIN IS THE PREDICTED IMPACT.

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3. Spiegel, Murray R., "Statistics, Theory and Problems," McGraw Hill Book Company.

4. Aerojet-General Corporation (Space General), "Rail Launch Dispersion and Wind Weighting Analysis," Report No. SG 1316TR-5/March 1970.

5. Novlan, David J., March 1974, "Unguided Rocket Impact Dispersion at WSMR," ECOM Data Report 821, Atmospheric Sciences Laboratory, U. S. Army Electronics Command, White Sands Missile Range, New Mexico. AD 779 375